ORIGINAL ARTICLE

Evaluating the use of Resuscitative Endovascular Balloon Occlusion of the Vena Cava (REBOVC) in Retrohepatic Vena Cava Injuries: Indications Technical Aspects and Outcomes

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Abstract

Aim: Vena cava injuries are a major challenge for trauma surgeons due to their difficult-to-access anatomical site. In addition, their complex operative management often requires prohibitive time for damage control purposes. Considering this scenario, endovascular techniques, such as endovascular occlusion devices, have been increasingly applied to treat such injuries. Resuscitative endovascular balloon occlusion of the vena cava (REBOVC) stands out as a promising technique to manage hemodynamically unstable patients - depending on the anatomical site of the injuries and the complexity of the access to them—since it enables temporary bleeding control to stabilize patients' conditions.

Methods: Based on a literature review about the use of REBOVC to manage venous bleeding deriving from the inferior vena cava (IVC). Four experimental studies were conducted with animal models, one descriptive study about the principles of occlusion in artificial models and four case reports were evaluated.

Results: REBOVC helped shorten the time necessary for bleeding control and increased the likelihood of achieving effective treatment in cases of potentially lethal bleeding, as well as reduced mortality rates.

Conclusion: REBOVC is a promising endovascular technique that can be used in a safer and more objective way to promote a new paradigm in IVC trauma scenarios to help to control bleeding and reduce its consequences.

Keywords: Abdominal trauma, Endovascular procedures, Injury, Vena cava.

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Introduction

Uncontrolled hemorrhagic shock is the main cause of early death in trauma patients.[1] Massive bleeding deriving from complex vascular injuries is a challenge faced by surgeons. It happens because most of these cases require the adoption of complex maneuvers to be controlled, a fact that significantly increases mortality rates–according to Parreira et al.[1–3] these cases account for 85.6% of causes of death in patients with penetrating abdominal trauma.

Inferior vena cava injuries account for high morbidity and mortality rates (36-75%).[4] According to estimates, less than 5% of patients with penetrating abdominal trauma have such an injury. On the other hand, IVC injuries in blunt abdominal trauma account for less than 0.5% of intra-abdominal vascular injuries.[5] Although this injury type is not so frequent, it is one of the most challenging and lethal injuries affecting trauma patients.[6]

Traditional approaches comprise the application of extensive and invasive techniques in sites of difficult surgical access. The following traditional approaches are often taken into consideration at the time to treat patients with retrohepatic IVC injuries: packing, which must be performed diligently to achieve any benefit; exposure (complex and time-consuming technique); direct repair (suitable for hemodynamically stable patients); and, in some cases, atriocaval shunt based on the classic technique (Fig. 1).[1,7]

A series-of-cases study was conducted at Ben Taub General Hospital in Houston (Texas) with 31 patients presenting trauma in the IVC; six patients were subjected to techniques such as exposure and repair, as well as all patients subjected to atriocaval shunt, have survived. Survivors presented postoperative complications: intra-abdominal abscess and respiratory failure accounted for 50% of complications, whereas postoperative hemorrhage was observed in 33% of cases. Therefore, despite these techniques, mortality rates remain high, since pre-hospital and preoperative blood losses, as well as hypovolemic shock, have a direct influence on hemodynamic stability and complications are often observed among these patients.[2]

Endovascular techniques have been described as alternatives with the favorable potential to treat exsanguinating trauma in

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structures such as pelvis, spleen, liver and kidney. The most recent technique - called REBOA—consists in installing an occlusion balloon catheter in the abdominal aorta, *via* the common femoral artery in zone one (near the diaphragm) or three (above the bifurcation of the iliac arteries).[8]

Several studies conducted in the last 5 years have shown superior REBOA performance in trauma patients in comparison to consolidated techniques such as resuscitative thoracotomy, since REBOA prioritizes brain and coronary perfusion, as evidenced by Ordoñez et al. who were pioneers in using this device in Latin America.[9]

REBOA is considered one of the gold standards for patients' resuscitation in damage control contexts, along with permissive hypotension, hemostatic resuscitation and damage-control surgery. According to the protocol suggested by Ordoñez et al., a calibrous access is placed in the femoral vein and another one is placed in the artery during the initial assessment advanced trauma life support (ATLS). They can be used, whenever necessary, to perform mass transfusion protocol (through the vein), as well as to monitor invasive blood pressure (through the artery). However, this access is mainly used to install an occlusion balloon catheter for the proximal control of bleeding sources to avoid hemodynamic decompensation and the "lethal diamond" of trauma–acidosis, hypothermia, coagulopathy and hypocalcemia.[3,9,10] Thus, a new paradigm has emerged in treatments applied to severe and hemodynamically decompensated trauma patients, based on endovascular technologies.[11]

At the same time, if one takes into consideration REBOA's principles, resuscitative balloon occlusion of the vena cava (REBOVC) emerges as a tool to be used in exsanguinating abdominal injuries involving the inferior vena cava (IVC) or its branches, due to penetrating or blunt abdominal trauma.

Thus, the aims of REBOVC using are to isolate structures and to control massive hemorrhages deriving from complex venous vascular injuries to enable repairing them at once, based on a faster and lesser invasive method. Nowadays, data collected in clinical and in animal studies have indicated that REBOVC can help improve hemodynamic and gasometric parameters by enabling temporary bleeding control.[12]

The aim of the current study was to present evidence of endovascular balloons used in injuries compromising the inferior vena cava in order to control bleeding and to enable a longer lifespan until definitive injury repair, based on a literature review.

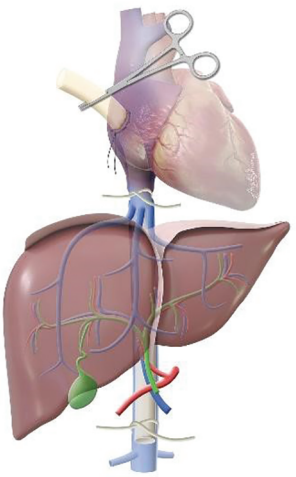

Fig. 1: Atriocaval shunt based on the classic technique. Adapted from Bardes et al. 2017

Methods

A survey of data in the literature about the topic 'REBOVC' was carried out based on descriptors such as hemorrhagic shock, balloon occlusion, or Inferior vena cava, not filter. PubMed, SciELO, LILACS and Google Scholar were the databases used for the search.

In total, 4,432 studies were found through the search in the databases and 192 studies were evaluated by five reviewers at the first stage of the current research, based on abstract and title reading. Inclusion criteria comprised studies that mentioned REBOVC, that were written in Portuguese, English and/or Spanish, and that were published in the herein selected databases in the last 5 years. Exclusion criteria comprised studies that did not use REBOVC as acronym for resuscitative balloon occlusion of the inferior vena cava or the central topic of the study, as well as studies that were not available in full, which led to nine studies that were read by two reviewers for this article, after screening.

Four studies were conducted with animal models, one descriptive study addressed the principles of occlusion in artificial models and 4 studies were case reports Flowchart 1.

Results

Mortality and hemodynamic stability stood out among parameters analyzed in the experimental studies, mainly through mean arterial pressure (MAP), cardiac output (CO) and heart rate (HR). REBOVC used in combination to REBOA recorded promising values for the parameters, but not for metabolic indicators such as pH and lactate. Furthermore, higher survival rates were associated with the use of REBOVC; this outcome has evidenced REBOVC's superior effectiveness in the investigated groups in comparison to controls (Table 1).

Vena cava injury with exsanguination was the main indication for the clinical application of the REBOVC procedure. The herein presented reports have mainly shown BP increase, bleeding stabilization and operative time shortening, which enabled faster (Table 2).

Thus, the use of REBOVC, when properly indicated, can be extremely beneficial to the management of hemodynamically unstable patients due to intra-abdominal hemorrhage, as observed both in the experimental studies and in the clinical cases reported above.

Discussion

Endovascular techniques have been addressed in the trauma context, due to their lesser invasive and resolutive feature of enabling intra-abdominal bleeding control. Thus, favorable outcomes were observed after these techniques were used in

Flowchart 1: Descriptive study addressed the principles of occlusion in artificial model

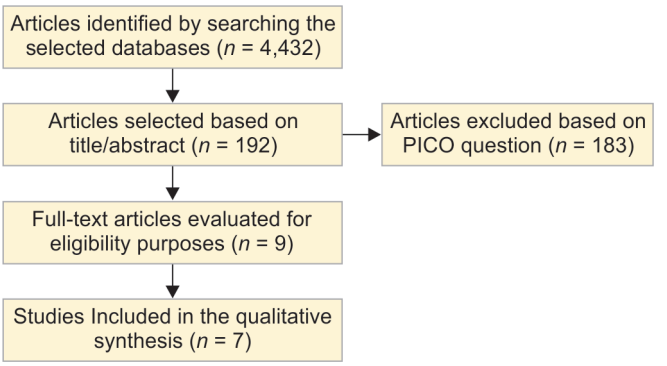

Table 1: Numerical and descriptive representation of the main findings in experimental and descriptive studies

Experimental studies						
Author	*Year*	*Study type*	*n*	*Main findings*	*Adopted model*	*Analyzed parameter*
Reynolds et al.	2017	Experimental	13 pigs	83.3% of 1-hr survival in the intervention group and 100% 1-hr mortality in the control group	IVC injury	Death after 1-hr intervention
Rezende-Neto et al.	2018	Experimental	7 pigs	MAP increase: 66 ± 5.8	Shock and suprahepatic IVC injury, hepatic vasculature exclusion for hemorrhage control	MAP
Wikström et al.	2019	Experimental	9 normovolemic pigs (11 REBOA + REBOVC combinations in zones 1 and 3, with, or without, pringle maneuver	REBOA + REBOVC in zone 1 enabled hemodynamic stability	Hepatic vasculature and IVC isolation to enable hemodynamic stability	Hemodynamic variables after 5-min intervention
Wikström et al.	2021	Experimental	25 pigs: Normovolemia + EBOA = 7; Normovolemia + REBOA + REBOVC = 6. Hemorrhagic shock + REBOA = 6; Hemorrhagic Shock + REBOA + REBOVC = 6	• Survival in hemorrhagic shock: REBOA + REBOVC > REBOA; • MAP, CO and CVP in Normovolemia and in shock: REBOA + REBOVC < REBOA ($p < 0.05$); • Lactate in Normovolemia: REBOA + REBOVC < REBOA ($p < 0.05$);	Comparing the use of REBOA to that of REBOA + REBOVC association in the occlusion of respective vessels for 45-mins, under normovolemic and hemorrhagic shock conditions	Survival, and hemodynamic and metabolic effects after 45-mins occlusion

Table 2: Numerical and descriptive representation of the main findings in clinical studies

Clinical studies						
Author	*Year*	*Study type*	*n*	*Outcome*	*Indication*	*Analyzed parameter*
Bisulli et al.	2017	Case report	1	BP = from 110/60 mm Hg to 125/70 mm Hg and HR bpm = from 100 to 75 bpm	Traumatic IVC injury	BP and HR
Bui et al.	2009	Case report	1	Bleeding control, faster injury identification and primary repair	Traumatic infrarenal IVC injury	Hemorrhage control
Ordoñez et al.	2016	Case report	1	REBOA zone 1 + retrohepatic REBOVC: SBP from 72 mm Hg to 100 mm Hg	Juxtahepatic venous injury	SBP, exsanguination cessation and survival

trauma patients, such as reduced intravascular volume loss and longer survival time.

Wikström MB et al. have conducted an experimental study with nine normovolemic pigs to help better understand the hemodynamic effects of venous occlusion (5-min), based on 11 different REBOA and REBOVC combinations with, or without, Pringle maneuver application. The investigated hemodynamic parameters comprised MAP, HR, CO, central venous pressure (CVP), mean venous pressure (MVP), and superior mesenteric artery flow (SMA) (in L/min). Based on these parameters, it was possible seeing that hemodynamic stability can be achieved through simultaneous use of REBOA and REBOVC, since such a combination provides the necessary control in extensive retrohepatic bleeding cases. The method can be used as an adjunct endovascular tool in severe trauma patients, who require temporary proximal and distal control of IVC and retrohepatic veins.[13]

Based on the same line of research carried out with pigs, it was possible reaching hemodynamic stability through simultaneous use of REBOA and REBOVC, which was followed by proper fluid resuscitation. However, greater metabolic and hemodynamic impacts caused by REBOA and REBOVC combination, such as higher serum potassium and lactate levels, should be taken into consideration, in comparison to the use of REBOA, in separate.[14]

Reynolds et al. have randomly used 13 pigs divided into two groups: seven animals were allocated to the control group, whereas

the other six were placed in the intervention group, which was subjected to REBOVC installation and inflation in the suprahepatic inferior vena cava. After both groups were subjected to IVC injury, animals were monitored for vital signs, as well as for gas and lactate concentration in arterial blood, until they died. Primary outcomes comprised blood loss and time until death, whereas lactate, pH, and vital signs were secondary outcomes. Animals in the control group have died 26 minutes faster than those in the intervention group, on average; they also presented lesser intravascular volume loss, whereas the group without endovascular intervention tended to present worsened acidosis, hypothermia and increased lactate levels. Thus, it was possible identifying the benefit of using REBOVC as a temporary bleeding control modality since it increases health teams' likelihood of controlling bleeding during damage control procedures.[12]

Rezende Neto et al. have developed an experimental model to perform total vascular exclusion in pig livers based on endovascular technique by using REBOA, Pringle maneuver and 2 REBOVCs for hemorrhage control. Seven monitored pigs were induced to hemorrhagic shock due to 35% intravascular volume removal, as well as subjected to suprahepatic vena cava injury. The procedure, which lasted 15 minutes, enabled interrupting suprahepatic bleeding, preventing hemorrhagic shock worsening, as well as increasing MAP.[15]

With respect to the clinical context, the first report described in the consulted literature about the use of balloon to treat IVC injury was carried out by Bui et al (2009).[15] The authors reported their experience with using an inflatable balloon catheter in infrarenal IVC injury caused by a gunshot wound. The device enabled hemostatic bleeding control and primary repair of the injury. The patient was discharged within one month without postoperative complications. In this case, the adopted strategy enabled significant surgical time shortening and blood loss reduction, as well as mitigated the risk of lethal triad development.[16]

In order to systematize the management of hemodynamically unstable patients subjected to penetrating trauma to the liver, Ordoñez et al. have proposed an algorithm to use REBOA (zone 1) together with REBOVC at retrohepatic vena cava level, in cases when the intra- and perihepatic packing and the Pringle maneuver are not effective in controlling active bleeding. Thus, they have achieved proximal and distal control of likely retro- and suprahepatic vessel injury, as schematically illustrated below. Penetrating liver trauma with retrohepatic vena cava injury is observed in Figure 2, whereas the use of the technique described above is depicted in Figure 3.[16]

Castelli et al.[17] reported a case of IVC injury close to the bifurcation of the iliac veins where endovascular balloon techniques were applied to stabilize blood loss and to promote local injury control to enable a lesser invasive and faster approach to this injury type.[17]

Bisulli et al. reported the successful use of endovascular balloon in IVC trauma; the procedure lasted 12 minutes and helped improve hemodynamic parameters: BP has increased from 110 x 60 mm Hg to 125 x 70 mm Hg, and HR decreased from 100 bpm to 75 bpm. This outcome enabled greater safety in the patient management process until the case was definitively solved since the patient also presented pelvic fracture and retroperitoneal hematoma identified in the imaging exam.[18] Similarly, Ordoñez et al. reported the use of REBOVC in juxtahepatic vein injury associated with the use of REBOA in zone 1; results have shown SBP increase from 72 mm Hg to 100 mm Hg after the device was installed.[16]

However, there are complications associated with the use of REBOA, such as vessel injury (rupture or perforation), embolism and peripheral ischemia. These complications can be mitigated by installing small introducers in patients at the initial assessment time, since introducing them in patients in severe health conditions can make the procedure more complex and increase the risk of injuries. In comparison to REBOVC, proximal occlusion, either used alone or in combination to other occlusive methods, can lead to a significant drop in systolic blood pressure (SBP) and cardiac output (CO). Therefore, it is necessary to gather greater number of evidences about likely complications associated with this method.[19]

The current study presented some limitations, such as the small number of cases effectively treated through REBOVC application in humans, since it was mainly restricted to case reports; experimental studies were the ones presenting the most promising and significant results. However, as the preliminary results were satisfactory, it is necessary to conduct further studies focused on establishing more solid criteria and indications to gather stronger evidence. Therefore, the endovascular technique described (REBOVC) has promising indications, and can be used in a safer and more objective way to promote a new paradigm in trauma scenarios.

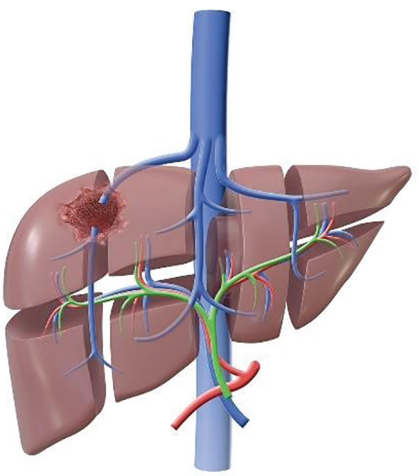

Fig. 2: Complex penetrating trauma to the liver. Adapted from Ordoñez et al. 2020

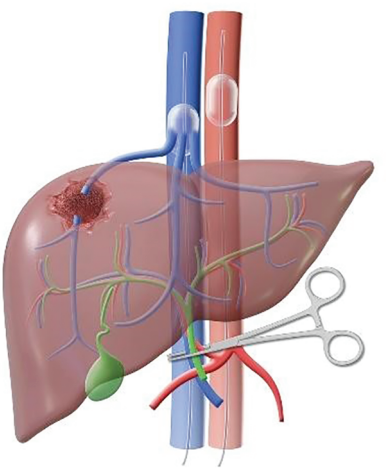

Fig. 3: Open endovascular isolation combined to REBOA, REBOVC and Pringle maneuver. Adapted from Ordoñez et al. 2020

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References

1. Kragh JF Jr, Littrel ML, Jones JA, et al. Battle casualty survival with emergency tourniquet use to stop limb bleeding. J Emerg Med 2011;41(6):590–597. DOI: 10.1016/j.jemermed.2009.07.022
2. Qasim Z, Brenner M, Menaker J, et al. Resuscitative endovascular balloon occlusion of the aorta. Resuscitation 2015(96):275–279. DOI: http://dx.doi.org/10.1016/j.resuscitation.2015.09.003
3. Parreira JG, Soldá SC, Rasslan S. Assessing the risk of death due to hemorrhage in victims of penetrating trauma to the torso admitted in shock: an objective method to select candidates for damage control. Rev Col Bras Cir 2002;29(5):256-266. DOI: https://doi.org/10.1590/S0100-69912002000500003
4. Kobayashi LM, Costantini TW, Hamel MG, et al. Abdominal vascular trauma. Trauma Surg Acute Care Open 2016;1(1):e000015. DOI: 10.1136/tsaco-2016-000015
5. Rehman ZU. Inferior vena cava injuries - a clinical review. J Pak Med Assoc 2020;70(6):1069–1071. DOI: 10.5455/JPMA.21107
6. Kauvar DS, Lefering R, Wade CE. Impact of hemorrhage on trauma outcome: an overview of epidemiology, clinical presentations, and therapeutic considerations. J Trauma 2006;60(6):S3–S11. DOI: 10.1097/01.ta.0000199961.02677.19
7. Bardes JM, Grabo D, Lam L, et al. Treatment algorithm and management of retrohepatic vena cava injuries. J Trauma Acute Care Surg 2017;83(2):340–344. DOI: 10.1097/TA.0000000000001538
8. Ribeiro MAF Jr, Feng CYD, Nguyen ATM, et al. The complications associated with resuscitative endovascular balloon occlusion of the aorta (REBOA). World J Emerg Surg 2018;13:20. DOI: 10.1186/s13017-018-0181-6
9. Ordoñez CA, Parra MW, Caicedo Y, et al. REBOA as a new damage control component in hemodynamically unstable noncompressible torso hemorrhage patients. Colomb Med (Cali) 2020;51(4): e4064506. DOI: 10.25100/cm.v51i4.4422.4506
10. Ordoñez CA, Parra WP, Serna JL, et al. Damage control resuscitation: REBOA as the new fourth pillar. Colomb Med (Cali) 2020;51(4): e–4014353. DOI: 10.25100/cm.v51i4.4353
11. Reynolds CL, Celio AC, Bridges LC, et al. REBOA for the IVC? Resuscitative balloon occlusion of the inferior vena cava (REBOVC) to abate massive hemorrhage in retrohepatic vena cava injuries. J Trauma Acute Care Surg 2017;83(6):1041–1046. DOI: 10.1097/TA.0000000000001641
12. Wikström MB, Krantz J, Hörer TM, et al. Resuscitative endovascular balloon occlusion of the inferior vena cava is made hemodynamically possible by concomitant endovascular balloon occlusion of the aorta-A porcine study. J Trauma Acute Care Surg 2020;88(1):160–168. DOI: 10.1097/TA.0000000000002467
13. Wikström MB, Smårs M, Karlsson C, et al. A randomized porcine study of the hemodynamic and metabolic effects of combined endovascular occlusion of the vena cava and the aorta in normovolemia and in hemorrhagic shock. J Trauma Acute Care Surg 2021;90(5):817–826. DOI: 10.1097/TA.0000000000003098
14. Rezende-Neto JB, Al-Kefeiri G, Strickland M, et al. Three sequential balloon catheters for vascular exclusion of the liver and aortic control (one REBOA and two REBOVCS): a hemorrhage control strategy in suprahepatic vena cava injuries. Panam J Trauma Crit Care Emerg Surg 2018;7(2):114–122. DOI: 10.5005/jp-journals-10030-1214
15. Bui TD, Mills JL. Control of inferior vena cava injury using percutaneous balloon catheter occlusion. Vasc Endovascular Surg 2009;43(5):490–493. DOI: 10.1177/1538574409339939
16. Ordoñez CA, Parra M, Millan M, et al. Damage control in penetrating liver trauma: fear of the unknown. Colomb Med (Cali) 2020;51(4): e-4134365. DOI: 10.25100/cm.v51i4.4422.4365
17. Castelli P, Caronno R, Piffaretti G, et al. Emergency endovascular repair for traumatic injury of the inferior vena cava. Eur J Cardiothorac Surg 2005;28(6):906–908. DOI: 10.1016/j.ejcts.2005.09.001
18. Bisulli M, Gamberini E, Coccolini F, et al. Resuscitative endovascular balloon occlusion of vena cava: An option in managing traumatic vena cava injuries. J Trauma Acute Care Surg 2018;84(1):211–213. DOI: 10.1097/TA.0000000000001707
19. Ordoñez CA, Herrera-Escobar JP, Parra MW, et al. A severe traumatic juxtahepatic blunt venous injury. J Trauma Acute Care Surg 2016; 80(4):674–676. DOI: 10.1097/TA.0000000000000979